



OBSERVATIONS ON FOREST PATHOLOGY IN GREAT BRITAIN AND DENMARK

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INTRODUCTION

In the past, Great Britain has paid little attention to growing forests as compared with other European nations. Timber needed was readily and cheaply imported from the Continent and from America, so a "laissez faire" policy was pursued. During the World War, however, the country was in desperate need of timber supplies for use at the front and in the service of supply. Space in ships needed for carrying troops and munitions had to be given over to rough lumber. On the other hand, the Central Powers had been able to maintain themselves effectively from their adequate and well-managed woodlands. At the conclusion of the war Great Britain found it essential to begin extensive reforestation and afforestation. Her woefully inadequate supply of timber, particularly softwoods, was almost completely exhausted. Furthermore, there were large areas of almost waste land in the highlands of Scotland, on which the population was steadily decreasing. Forests on such land would give employment and increase the population.

Unfortunately there is only one conifer of commercial value native to Great Britain, that is, Scotch pine (*Pinus sylvestris* L.), and even its native-

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ity is subject to dispute. This species, together with European larch (*Larix europaea* D.C.), introduced so long ago that many believe it to be native, comprised the bulk of the softwoods grown. These two trees grow slowly, however, and fast-growing trees were needed. Furthermore, they are quite unsuitable to certain sites which cover extensive areas.

While in the past the British, with some exceptions, have been little interested in forestry, they have been enthusiastic arboriculturists, so that specimens of conifers of considerable age from all over the world may be found on the island. These showed that species from that portion of the Pacific Coast of North America north of the California line and west of the summit of the Cascade Mountains were particularly suitable for culture. In fact certain of these species in Britain grow more rapidly, in their youth at least, than they do in their native home. This is probably explainable by climatic differences. In England and Scotland the summers are normally mild and moist—moderate temperatures, abundant showers, and high humidity, while at home during the same period the trees are subjected to relatively high temperatures and long periods of drouth. Mild, wet winters are the rule in both regions.

Of the conifers from the Pacific Coast, Douglas fir (*Pseudotsuga taxifolia* (Lam.) Br.) is most extensively planted, followed by Sitka spruce (*Picea sitchensis* (Bong.) Trautv. and Meyer). Grand fir (*Abies grandis* Lind.) has found considerable favor. Western red cedar (*Thuja plicata* Don.), Port Orford cedar (*Chamaecyparis lawsoniana* Parl.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are used to some extent. Noble fir (*Abies nobilis* Lind.) is being tried in a small way. Japanese larch (*Larix leptolepis* Murr.) is the only oriental species commonly planted. The continental European species most used are Norway spruce (*Picea excelsa* Lk.) and European larch. Silver fir (*Abies pectinata* D.C.) has rapidly declined in favor, owing to the ravages of the silver fir aphid (*Dreyfusia nuesslini* Börner), presumably imported from the Continent, where it is common on the same host but doing much less damage. Among the pines, Scotch pine is still most fancied, but maritime pine (*Pinus pinaster* Sol.) and Corsican pine (*P. laricio* Poir.), both native to southern Europe, are extensively used. Lodgepole pine (*P. contorta* Loud.) from the northern Rocky Mountains is being experimented with.

But as far as private owners are concerned, the species which is playing a very large part in the planting campaign is Douglas fir, on account of its phenomenal rate of growth. This tree, first introduced into England in 1827 (9, p. 35), almost 100 years ago, was not planted commercially until 1860 and then not in an appreciable amount until the first years of the present century. Extensive planting followed the war.

Douglas fir is also one of the most valuable species in the United States. At present it comprises about one-fourth of our remaining merchantable timber, and its continued existence, owing to its ease of reproduction, its rapidity of growth and its simplicity of management, is of paramount importance to the future softwood supply of this country and to the economic well-being of the Pacific Northwest.

BRITISH NAMES FOR AMERICAN CONIFERS

In the United States only one species of Douglas fir, *Pseudotsuga taxifolia* (Lam.) Britt., is recognized throughout the West. In Great Britain and in fact over all of Europe this American species is considered to include two distinct species and one variety, that is, *P. douglasii* Carr., commonly called coast, Pacific Coast, Oregon, or green Douglas fir; *P. glauca* Mayr. known as mountain, Rocky Mountain, Colorado, or blue Douglas fir; and *P. douglasii* Carr. var. *caesia* Schwer., termed Fraser River or intermountain Douglas fir. The name Fraser River is an unfortunate misnomer, since the Fraser River has its source in the northern Rocky Mountains and empties in the Pacific Ocean, so that green Douglas fir as well as the intermountain variety are found along its banks, and probably the blue Douglas fir besides.

It is not within the province of this paper to discuss the relative merits of the American and European species-concepts of Douglas fir. The latter has been well presented by Henry and Flood (8) and Hickel (9). Suffice it to say that the two species as recognized in Europe are at least biologically so different, particularly in their rate of growth and reaction to disease, that in this paper it seems advisable to adopt the European classification for the sake of clarity.

The British also subdivide certain other species of American conifers, and in other cases the specific name used is not in accordance with the one accepted here. A table of synonyms for a few of the more important species on which there is a difference of opinion follows:

AMERICAN NAME	BRITISH NAME
<i>Abies concolor</i>	<i>Abies concolor</i>
White fir	Colorado white fir
<i>A. concolor lowiana</i>	<i>A. lowiana</i>
Pacific white fir	Low's white fir
<i>A. lasiocarpa</i>	<i>A. sub-alpina</i>
Alpine fir	Alpine fir
<i>Pinus contorta</i>	<i>Pinus contorta</i>
Lodgepole pine	Beach pine
	<i>P. murrayana</i>
	Lodgepole pine

<i>P. radiata</i>	<i>P. insignis</i>
Monterey pine	Insignis pine
<i>Tsuga heterophylla</i>	<i>Tsuga albertiana</i>
Western hemlock	Hemlock spruce

IMPORTANT DISEASES

Canker

A most important disease primarily of Douglas fir is canker, presumably caused by *Phomopsis pseudotsugae* Wilson. The effect of this fungus on the host, resulting in die-back of the young shoots and canker of the stems, has recently been adequately described and figured by Wilson (27). The parasite has probably been present in Europe under various names for many years but it is only recently that it has received serious consideration, when with the extensive planting of Douglas fir in Great Britain the damage caused by the fungus has become appreciable. Rostrup (19), in 1890, described *Phoma pithya* Sacc., which he considered identical with *Phoma abietina* Hart., attacking the shoots of Douglas fir and silver fir in Denmark, and in 1906 (20) listed it from Bornholm, a small island in the Baltic Sea about 100 miles east of Copenhagen. However, specimens collected on this island by the writer in September, 1925, from Douglas fir, said by the head forester to be infected with *Phoma pithya*, were found upon critical study to be attacked by *Phomopsis pseudotsugae*. Böhm (1), in 1896, described and figured a canker disease on Douglas fir in Germany which he attributed to *Phoma abietina*, but which from his description is the same as *Phomopsis pseudotsugae* in its effect on the host. Somerville (22) mentions *Phoma pithya* on Douglas fir in Scotland as early as 1898. Hickel (9, p. 31), mentioning the diseases of Douglas fir in Europe, lists *Phoma pithya*, *P. abietina*, and *Phomopsis pseudotsugae* as synonymous; while Visart and Bommer (24, p. 302) report *Phoma pithya* on Douglas fir in Belgium. De Koning (13), in 1922, records *Phoma pithya* on Douglas fir in Holland. In France, Prillieux and Delacroix (18), in 1890, described *Fusicoccum abietinum* (Hart.) P. and D. on silver fir which later was shown to be identical with *Phoma abietina*.

Wilson (27, pp. 13, 28-31), in his bulletin on *Phomopsis pseudotsugae*, recorded the fungus on Douglas fir and Japanese larch, cited a single instance on European larch, and reported one of *Diaporthe pithya* Sacc., presumably the ascigerous stage of *P. pseudotsugae*, attacking lowland white fir (*Abies grandis*). Wilson separates the species on the following basis.

Phoma abietina (from specimen determined by Hartig). With sporophores, conidia $12-14 \times 5-6 \mu$, somewhat angular in outline.

Phomopsis pseudotsugae (from specimens). With sporophores, conidia $5.5-8.5 \times 2.5 \mu$, regular in outline.

Phoma pithya (from description only). No sporophores.

There is also a difference in the structure of the pyrenidium of *Phomopsis pseudotsugae* and *Phoma pithya*. A critical study of the type collection of *P. pithya* may show it to be identical with *Phomopsis pseudotsugae*.

The three species are so closely related that they have been badly confused. It will require intensive work to straighten out the present confusion in nomenclature in order to determine the history and distribution of *Phomopsis pseudotsugae* in Europe. The fungus is actually present in Great Britain and Denmark, and for practical purposes it must be considered as present in Germany, Holland, Belgium, and France. In Great Britain the canker was found to be much more common in the comparatively moist, cool regions of Wales and Scotland than it was in the dry, warm parts of England such as Norfolk, Suffolk, and Hampshire. This indicates that the disease will be found more widespread in northern than in southern Europe. As yet the fungus is not known in North America, although Hahn (6) has recently found another *Phomopsis* on Douglas fir in nurseries in the eastern United States. This investigator is now in Great Britain studying the problem further.

So far, the canker is essentially a disease of young trees, and no indications of it have been found on large, mature individuals. Furthermore, it is practically confined to the green form and rarely attacks blue Douglas fir. This was strikingly apparent in the infection on Bornholm. Quite severe damage has occurred in plantations, just after the trees have been set out, by the killing back of the leading shoot, resulting either in the death of the tree or a bunchy-topped, slow-growing survivor. Larger trees may be killed by the canker girdling the stem, but no tree over 2 inches diameter breast-high was seen killed in this way. As a rule most trees which have succumbed were less than 8 feet in height. The largest tree seen with a stem canker was 8 inches diameter breast-high just above the canker. This was in Denmark.

There are two ways in which stem cankers originate: through the tip infection of a living lateral with subsequent spread to the stem, and by direct inoculation of the stem through a wound. There is no evidence that infection can occur through uninjured bark. While the former method of infection on the stem of seedlings and small saplings is not uncommon, it is not frequent in stands varying from the large sapling to small pole size where very few living lateral shoots are to be found on the lower stems, the branches having been uniformly killed by shading. In such stands wounding is all-important: without wounds the trees remain practically

free from canker. Wounding, nearly always the result of human carelessness, can be prevented and the canker on stems of trees from large sapling to small pole sizes largely controlled. The two worst cases of stem cankers observed were in Wales, where a stand of large saplings had been badly wounded by pruning, and on Bornholm, Denmark, where many wounds had occurred from thinning. In both plantations practically every wound had resulted in a canker.

The Japanese larch was occasionally found attacked by *Phomopsis pseudotsugae*, but always in plantations that had been pruned or thinned. Only one form of the disease was seen, that is, cankers on the main stem. No killed trees were noted. No die-back of the tops or branches was observed. The cankers on Japanese larch are not quite like those on Douglas fir. The most striking difference was that of greater size, the cankers on larch sometimes having a vertical extent of 2 feet, while those on Douglas fir rarely exceeded 8 inches. Furthermore, the margins of the cankers on larch were marked by a pronounced exudation of resin.

This parasite would be an extremely dangerous one, capable of killing trees up to a considerable size except for the fact that canker development persists only through the winter and spring following infection and apparently stops completely when the host resumes active growth in the spring. It is noteworthy that the fungus *Neofabrea malicorticis* (Cordley) Jackson, causing a similar canker on apple trees in the Pacific Northwest, behaves in the same way (12, pp. 178-179). Wilson (27, p. 21) reports a single exception to the foregoing habit—the case of a canker which continued development over a four-year period. Since the cankers develop rather slowly, particularly horizontally, it is possible for only a rather small stem to be girdled, unless several cankers coalesce, which does not often happen.

The most serious damage seen by the writer was near Murthly, Scotland, where a plantation of 10- to 11-year-old Douglas firs was only about 50 per cent stocked, on account of killing by *Phomopsis pseudotsugae* during the years 1920-1922. The bare spots had been replanted in 1921, but most of the new trees had been immediately killed. This is a very serious loss, judged even by present American standards which are necessarily less rigorous than European ones.

Our standard is a fully stocked stand at maturity, so that any disease which does not reduce the final stocking or the increment can not now be considered of importance, since thinning is not economically practicable. But in Great Britain, where it is hoped to realize on thinnings, the death of any young trees in a plantation is a loss, particularly when planting costs due to drainage work, cutting ferns and brambles, and rabbit fencing, trapping or shooting amount to from 4 to 10 pounds (approximately 20 to 50 dollars) per acre, as contrasted with 15 dollars on national forests in the Pacific Northwest.

But in most of the infected areas seen throughout Great Britain the actual damage would be considered slight if occurring in stands of identical age and size in the Douglas fir region of the Pacific Coast. Nevertheless this parasite must be considered a serious potential danger to the Douglas fir in North America, for enough was seen in Great Britain of the virulence and change in life habits of imported parasites more or less innocuous in their native haunts to realize that in general it is hazardous to predict what any fungus will do in a new environment. To be sure, the artificially created (planted) stands of Europe are inherently more subject to disease than the naturally regenerated stands of western North America, but, on the other hand, the discontinuous nature of the stands abroad is in itself a measure of protection against parasitic attack, while the continuous area of practically pure Douglas fir extending over hundreds of square miles in this country is an ideal situation for an epidemic. Considering the fact that Douglas fir at present comprises about one-fourth of all the merchantable timber in the United States and will always occupy a highly important position, there is much at stake.

Consequently this disease must be studied further. It is not yet proved by inoculations that Douglas fir canker is actually caused by *Phomopsis pseudotsugae*, the evidence so far being constant association of the organism with the disease—excellent as far as it goes. However, information is not complete on the method of infection, origin of the disease, its original host, its present distribution, and its relation to somewhat similar diseases which have figured in European literature. The origin of the fungus is extremely important. If it could be proved that it came from the Douglas fir region of North America, our problem would be solved: the parasite would no longer be a potential danger. In the writer's experience in the Douglas fir region, nothing similar has been seen, and it is his reluctant opinion that the organism is a European or other foreign fungus, normally saprophytic, which has become parasitic on two introduced species, Douglas fir and Japanese larch.

Needle Cast of Douglas Fir

Needle cast caused by *Rhabdocline pseudotsugae* Syd., first described by Weir (26) and later named by Sydow (23, pp. 194–195), has so far been reported in Europe at only two places—near Stobo, Peeblesshire, Scotland, and at a point 8 miles distant to which it has apparently spread from Stobo (29). The fungus was probably brought in directly from western North America where it is ubiquitous, since importations of Douglas fir have been made in the past to the place where the parasite was found.

The disease seemed even more virulent than in America, a heavy attack of it for four successive years having reduced the height growth of the most

severely attacked trees to a few inches per season. The intermountain Douglas fir was most severely injured, followed by the blue variety, while the valuable green form was not affected. If the parasite continues in this way, neglecting green Douglas fir, it will not cause much damage in Great Britain, since planting of the other two varieties of Douglas fir will be very restricted owing to their slow growth. There is of course a continual danger that a strain of the fungus to which the green Douglas fir is susceptible may be imported or that the present strain may ultimately adapt itself to the green form.

Douglas Fir Aphid

The most serious injury to green Douglas fir observed was caused by the aphid (*Chermes cooleyi* Gill.). This insect, originally imported from North America where it occurs throughout the range of Douglas fir, was found in greater or less degree in practically every Douglas fir plantation visited in Great Britain. It was not noticed on the island of Bornholm in Denmark. It has been described by Chrystal and Storey (3).

The insect rarely, if ever, kills the trees attacked, but where infestation is heavy there is a decided suppressing effect on individuals and stands. No trees escape in a heavy infestation. One plantation of trees from 10 to 15 feet high which normally grew from 15 to 36 inches per annum has been reduced for the past two years to an average annual height growth of from 3 to 6 inches. In another plantation of Douglas fir mixed with western red cedar the first named species was badly overtopped by the latter, due to *Chermes cooleyi* on the Douglas fir, while under normal conditions the Douglas fir would have grown much faster than the cedar. Infestation was always most severe in open stands or on the marginal trees in dense stands.

This insect in Great Britain is another classic example of a marked change in life habits of a parasite in a new environment. In North America it is practically innocuous, while in Great Britain it has become extremely virulent on the green Douglas fir only, rarely being found on the blue form. Furthermore, in America it also attacks Sitka spruce, causing cone-like galls on the twigs and at times severely injuring young trees, but in Britain the Sitka spruce strain has not yet been found, although young Sitka spruce is growing in many places immediately adjacent to or in the immediate vicinity of infested Douglas fir. Of course there is still some doubt as to whether the form on Douglas fir and the gall-causing form on spruce are actually one species.

Just what the future of this parasite in Great Britain will be is problematical, but from present indications, when the epidemic gains momentum, the consequences will be serious. Even though older plantations may be little affected by the attack, there will be a marked reduction extending over

several years or more in the annual increment of younger plantations, necessitating a corresponding increase in the rotation. Hope of control lies in the introduction from North America of the natural parasites of the insect and the selection of favorable sites for Douglas fir plantations.

Silver Fir Aphid

The silver fir aphid (*Dreyfusia nuesslini* Börner) was apparently introduced into Great Britain from Continental Europe where it is widely distributed but not exceedingly virulent on silver fir. In 1925 the aphid was widespread in Britain, the damage to silver fir being so severe that the further planting of this species may have to be discontinued.

Needle and Twig Blight of Firs

Rehmiellopsis bohémica Bub. and Kab., recently discussed by Wilson and MacDonald (28), attacks the needles of the current year on several of the true firs. In severe infections the majority of the season's needles on each shoot are killed, resulting in the death of the shoot during the course of the growing season. If a severe attack is sustained over several seasons the stand is badly injured and many trees may die.

This was the case with a young stand of silver fir at Inverliever, Scotland. Here the fungus, working in combination with the silver fir aphid, was so steadily killing a stand of young trees up to 20 feet high that in a few years the entire stand would be wiped out. These trees, however, were on a very unfavorable site, which in the writer's judgment had much to do with the sustained intensity of the attack. On Bornholm, where silver fir is grown extensively on good sites, there had been an epidemic of this fungus during the 1924 season, but for some years previous it had been little in evidence, and an examination in September, 1925, showed that the summer's attack had been very light.

The only American species found attacked by *Rehmiellopsis bohémica* was noble fir. A small plantation on a poor site in Scotland was being severely injured in spite of attempts at control by cutting out the diseased portions. The aphid was not present on these trees.

Needle and Twig Blight of Pines

At various places in Scotland certain pines were suffering rather severely from needle and twig blight of pines caused by *Brunchorstia destruens* Eriks., which appeared to be spreading. The fungus was described on the continent years ago by Brunchorst (2) and Schwarz (21), the latter considering it to be the imperfect form of *Cenangium abietis* (Pers.) Duby, but it has only recently come under Dr. Wilson's observation in Great Britain.

At one place in Scotland where the parasite was observed, Swiss stone pine (*Pinus cembra* L.) was being so badly damaged that it seemed only a question of time until this species would be eliminated from the locality. The fungus was killing the tops and branch tips of the trees from 5 to 20 feet high to such an extent (the oldest about 25 years old) that many were dying and all were in more or less unhealthy condition. Swiss mountain pine (*P. montana* Mill.), western white pine (*P. monticola* Dougl.) and lodgepole pine were attacked, although not so severely as stone pine. The trees were all occupying a very poor site.

On another estate Corsican pine was being severely injured, while the mountain pine was less seriously affected.

White Pine Blister Rust

Very little white pine blister rust (*Cronartium ribicola* Fisch.) on 5-needle pines was seen in Great Britain, for there were relatively few pines of this group to be found. The disease was abundant in places on cultivated black currant (*Ribes nigrum* L.). Planting of 5-needle pines has been definitely abandoned because of blister rust, the opinion of British foresters being that it was poor policy to plant any species that would have an added charge against it for protection, when other species could be substituted. In the writer's opinion, there are places in Great Britain where 5-needle pines can be grown with little or no increased cost because, on the whole, wild currants or gooseberries were found to be rare.

On the island of Bornholm in Denmark, eastern white pine (*Pinus strobus* L.) was badly damaged by blister rust. No wild currants or gooseberries were seen; infection came entirely from European black currants in farm gardens at distances of 300 to 3,300 feet from the pines, no difference in degree of infection of the white pines being apparent as the distance from the currants increased. This locality afforded the most valuable evidence of the terrific damaging power of the European black currant. This currant can not be tolerated in a region where white pines are grown.

Needle Cast of Larch

Needle cast, very common on young European larch throughout Great Britain, is caused by the fungus *Meria laricis* Vuill. It results in the death of needles on young trees and particularly of the young needles on the long shoots. It was most serious in nurseries, where heavy losses have occurred during the past few years, seedlings and transplants being killed by defoliation. The fungus in Great Britain has been described by Hiley (11).

Larch Canker

In the past, canker on European larch caused by *Dasyscypha calycina* (Schum.) Frick. had been so destructive in Great Britain that the future

cultural value of this tree seemed very uncertain. In fact considerable damage is still being done. This disease has been described by Hiley (10, pp. 16-79).

But foresters, in the light of long experience, now feel that in the main this disease can be controlled by proper silvicultural methods. Larch has been planted indiscriminately on all types of site; it has been planted too thickly and stands have been allowed to stagnate. By avoidance of low, poorly drained sites, by wider spacing and judicious mixture in planting, and by early thinning in order to admit plenty of light and air, it is believed that relatively healthy stands of European larch can now be grown.

Cedar Leaf-Blight

Leaf-blight of western red cedar caused by *Keithia thujina*, which has been discussed by Weir (25), has been found during the past few years at a number of widely isolated points in England, Scotland, and Ireland (4, 5, 14, 16, and 17). As yet little is known as to what it may do, but so far wherever it has occurred it has been extremely severe. The parasite was apparently introduced from America, but the British authorities are somewhat puzzled by its sudden appearance in remote localities where no nursery stock has been known to have been introduced.

Root Rots

The two important root rots were caused by the honey fungus (*Armillaria mellea* (Vahl.) Quel.) and by *Fomes annosus* (Fr.) Cke.

The honey fungus seemed to attack all species and sizes of conifers although young trees in the sapling stage were most susceptible. It was particularly bad in plantations of conifers on cut-over areas previously occupied by old, overmature stands of oak. Much oak forest in Britain is being converted into softwoods. Corsican pine was by far the most susceptible of all the conifers observed.

Fomes annosus was also found attacking various species of conifers, being particularly severe on Norway spruce, silver fir, and Douglas fir. While trees up to 6 inches diameter breast-high and larger were seen which had been killed by the fungus, those in the sapling stage suffered most. Japanese larch was not immune from this fungus.

Chestnut Blight

The discovery of *Endothia parasitica* (Murr.) A. and A. on chestnut in Belgium and on a staging pole in London by Metcalf (15) in 1923 indicated that the fungus might be present in Great Britain, but, although chestnut was examined at various places, the disease was not found. The chestnut orchards in Kent were not visited.

The foregoing discussion on a few important forest tree diseases is merely to call attention to some parasites in Great Britain which are potentially dangerous to this country and to present examples of how introduced parasites can change their habits, particularly their virulence, in a new environment.

STRAINS OF FOREST PARASITES

Even a superficial study of forest tree diseases in Europe, particularly those introduced from North America, clearly points to the existence and importance of strains, biological species, or physiological species in forest tree parasites. Among the European organisms Hiley (10, p. 79) mentions two different growth forms of larch canker (*Dasyscypha calycina*), a saprophytic and a parasitic form.

Throughout the native range of Douglas fir the needle-cast fungus is found. In Scotland the fungus was attacking only the blue and intermountain varieties, neglecting the green. The Douglas fir aphid, on the other hand, so far has virtually confined itself to green Douglas fir throughout Great Britain, very rarely being found on the blue form, while in its native home it infests all forms of the host. *Phomopsis pseudotsugae*, presumably a native to Europe, was not found attacking blue Douglas fir, although it occasionally does, but was common enough on green Douglas fir.

Fomes annosus was commonly killing young conifers in Great Britain and Denmark. This fungus is often found in the Pacific Northwest on old stumps or dead trees and occasionally causes root rot and butt rot in a mature tree, but it very rarely infects young trees.

Black poplar (*Populus trichocarpa* T. and G.) in the Pacific Northwest is commonly infected by the yellow leaf blister caused by *Taphrina aurea* (Pers.) Fr., which is also found on the Lombardy poplar (*P. nigra* L. var. *italica*) in the same region but frequently not in the same locality. The fungus was observed in a nursery in Scotland on the leaves of saplings of *P. generosa* Henry, *P. laurifolia* Led., and *P. nigra*, about 4 feet high. *P. nigra* was most heavily infected. *P. trichocarpa* in the same block and with its leaves intermingled with the diseased *P. generosa* was absolutely free from infection.

The foregoing conditions show clearly that strains do exist in certain species which are represented in America, on the polymorphism of which there is little or no information. It is, of course, much easier to see this in Great Britain, where the various growth forms of conifers of wide distribution are planted side by side, than it is in America, where the species occur naturally over thousands of square miles and direct comparison is rarely possible. These conditions also indicate a pathological as well as a

morphological basis for the separation of Douglas fir into two distinct species as is done by the British.

QUARANTINE PROTECTION

In the past, forest trees, particularly conifers, have been imported indiscriminately into Great Britain from all over the world, and in some measure this is still going on. Neither the quarantine laws nor the inspection force are adequate, while there are the usual difficulties in properly enforcing such laws as do exist.

Fortunately, or unfortunately, Great Britain has never had a disastrous plant disease epidemic. If she had, the country might be awake to the need for more careful regulation of the importation of nursery stock. The elm disease, probably caused by bacteria (*Micrococcus ulmi*) and probably introduced during the World War, is now rapidly killing the trees in Holland and nearby sections of Germany, Belgium, and France, but has not yet crossed the channel.

But some very dangerous diseases have been brought in. From North America have come the Douglas fir aphid and the Douglas fir needle cast, the former already wide-spread and serious on, and the latter potentially dangerous to, Douglas fir, while the cedar leaf-blight is becoming increasingly bad on western red cedar. From continental Europe the silver fir aphid has arrived.

It would seem that the discontinuous nature of the stands would greatly retard the spread of those diseases practically confined to one host species. This would probably be so except for the indiscriminate movement of nursery stock about Great Britain and Ireland, in some cases even when it is known to be diseased. Great Britain, occupying an isolated island, has had a good opportunity to keep her forests free from foreign parasites. This chance has been largely lost by the unregulated importation of young trees.

There is a lesson for the United States in this. Our quarantines are the only safeguard that will prevent the introduction of several known, potentially dangerous forest tree diseases and undoubtedly many of which we have no knowledge. Any weakening of our quarantine laws or policy will result in increased future expenditure for control. Another point of primary importance must be considered. It may be just as dangerous to introduce a foreign strain of an indigenous parasite as it would be to let a new species come in. For example, the strain of *Fomes annosus* observed in Great Britain, if introduced into the Douglas fir region of the Pacific Northwest, might prove highly virulent, whereas the fungus as it exists there at present is of trivial importance.

FACTORS FAVORING DISEASE

In silviculture in Europe, and particularly in Great Britain, certain practices are common which predispose stands to diseases of epidemic character. It is axiomatic in crop production that intensive culture increases the danger from disease, and timber growing in western Europe is decidedly intensive.

Clear cutting followed by planting, almost universal in Great Britain, in itself predisposes stands to attack by fungus and insect parasites. In Denmark natural regeneration is practiced wherever possible, and it was noteworthy that Skovrider K. Bramsen, in charge of the state forest of Almindingen, repeatedly emphasized the greater amount of disease, particularly root rot caused by *Fomes annosus*, in the planted stands as compared to those established by natural regeneration. In Switzerland clear cutting is prohibited by law. The complete and sudden exposure of the forest soil resulting from clear cutting is considered very detrimental, resulting in a continuous lowering of the thrift of the timber crop over successive rotations.

In addition, on private holdings the British are tending toward a short rotation, as low as 40 years where possible. Furthermore, species are planted pure to a large extent, although foresters are striving more and more to find suitable mixtures. Pure stands are the most susceptible to fungus and insect attacks, consequently much of the woodland in Great Britain, consisting of pure planted stands managed on a short rotation and clear cut with the consequent exposure of the forest soil at more frequent intervals, is inherently susceptible to disease. The present silvicultural and economic ills of the pure, planted Norway spruce forests of Saxony are a classic example of the price that may finally have to be paid for continuous clear cutting and planting of a single species on a short rotation.

Proper selection of site is also very important. Since most of the conifers grown in Europe have been introduced from other regions, it was not known to just which sites the various species would be adapted, and at first little attention was paid to this. The results in many cases were disastrous. Stands on unsuitable sites grew slowly, were not thrifty, and sooner or later largely succumbed to insect or fungus attack. This has been well illustrated by Scotch pine, European larch, and silver fir.

Larch planted in dense, pure stands on low, moist or otherwise unfavorable sites with poor soil suffered severely from larch canker, while stands on favorable sites with good soil remained practically free from disease. To be sure it is not always possible to determine immediately the most suitable site for an introduced species, but sometimes even reasonable care has not been taken. A young stand of silver fir was seen in Scotland planted

on an exposed site in very poorly drained peat soil. The trees were rapidly being destroyed by two needle and shoot parasites, *Rehmiellopsis bohémica* and *Dreyfusia nuesslini*. Again in Wales, Douglas fir was found planted in soil only about a foot deep with an underlying, impervious, clay subsoil. The trees about 10 to 15 feet high were so far thrifty and growing rapidly, but it is a reasonable prediction that before many years there will be heavy losses in this stand from uprooting by wind or wet snow, if nothing else. Already damage by the latter has begun. In addition, the stand will ultimately stagnate.

The source of seed is another factor which has been too little considered in the past, but British foresters now feel that the inferiority of some of the present stands of Scotch pine and European larch is due to the fact that the seed came from localities on the Continent well outside the range for the optimum development of the species. Such inferior stands, of course, are quite susceptible to disease—for example, the susceptibility of the larch to canker. This general principle must be recognized and carefully considered for all species.

So far in America it has not been necessary in most forest regions to consider seriously the questions discussed above, but as silviculture here becomes more intensive and European practice is approached, the same difficulties will arise in some cases. However, as long as the majority of our managed forests of the future in this country are composed of native species naturally regenerated, with as little deviation from the original composition of the stand as possible, losses here from indigenous parasites should not be excessive.

CONCLUSION

There is one great lesson for American forestry in the existing situation in Great Britain: protect our native species.

The introduction of foreign nursery stock is a most dangerous practice; it may at any time result in another disastrous epidemic similar to chestnut blight or white pine blister rust. Foreign species should be introduced only as seed and the stock grown here. But any exotic tree is an uncertain quantity and if introduced should be grown only experimentally for a long term of years, for it is not until the end of the rotation that final judgment can be rendered as to the success or failure of an introduction. First, there is the problem of securing seed of the best quality from the optimum, native range of the species; second, the difficulty of proper site selection; and, finally, the possibility that the species sometime in its life may be attacked by an indigenous parasite hitherto innocuous. Any one of these factors can spell failure. For the native species, seed collection plays a minor part since natural regeneration is depended on mostly, the optimum sites are

known, and the indigenous parasites, while quite severe in some cases, never threaten the existence of any species. Those who suggest introducing a foreign species to replace a native tree already attacked by disease, instead of protecting the latter, if that is possible, are in a large measure advocating deferred trouble.

The introduction of an exotic tree species is, on the whole, a hazardous undertaking, but it is far more so in this country than in Europe, owing to our extremely inadequate knowledge of the suitability of foreign species to the various forest regions of the United States. Abroad, different exotic tree species had been grown in arboreta for a long time before they were established as components of the forest. This was particularly true in Great Britain, and is a practice which should be generally initiated at once by our own country where there are few arboreta, especially in the western states. Costing little to start or maintain, an arboretum nevertheless requires a long time to develop, since raising trees from seed is a slow process, and complete results can not be expected until the trees are mature. Arboreta or experimental plantings for testing exotic species should be maintained by all the forest schools and forest experiment stations. No other activity will yield a greater commensurate reward for the expenditure involved. In the future, circumstances which can not be foreseen or controlled may compel the widespread establishment of a foreign tree species. Only with knowledge gained from arboreta and experimental plantings can such a situation be adequately met.

Finally, by carefully following literature, corresponding with foreign workers, and actually studying conditions on the ground in those countries most closely united commercially with our own, forest pathologists in this country must obtain an extensive knowledge of exotic diseases of trees. In this way, if a foreign parasite is introduced, and we already have a knowledge of its life history and habits, priceless time can be saved in its detection and the initiation of eradication or control measures. The value of such information at the outset of the white pine blister rust or the chestnut blight epidemics, for example, would have been beyond estimation.

SUMMARY

1. This paper presents observations during 1925 on the pathological condition of various conifers introduced into Great Britain and Denmark, particularly species from the western United States.

2. Douglas fir is attacked by *Phomopsis pseudotsugae*, *Rhabdocline pseudotsugae*, and *Chermes cooleyi*; silver fir suffers severely from *Dreyfusia nuesslini*; various true firs are injured by *Rehmiellopsis bohémica*; while pines are damaged by *Brunchorstia destruens*.

3. In Great Britain planting of 5-needle pines has been discontinued on account of the ravages of *Cronartium ribicola*; and on the island of Bornholm, in Denmark, eastern white pine was found severely infected by this rust. Nursery stock of European larch is commonly defoliated partially or completely by *Meria laricis*, while the older trees are frequently cankered by *Dasyscypha calycina*. Western red cedar is attacked by *Keithia thujina*, causing leaf blight. Root rots caused by *Armillaria mellea* and *Fomes annosus* are common on conifers.

4. The existence of strains of certain forest tree parasites not regarded as polymorphic in North America is quite apparent in Great Britain.

5. Several dangerous forest tree diseases have been brought into Great Britain, which indicates the need for careful regulation of the importation of nursery stock.

6. Certain practices, such as the culture of pure stands of one species on a short rotation followed by clear cutting, predispose stands to disease. In addition, plantations have sometimes been established on poor sites. The source of seed also has not always received proper consideration.

7. Foreign species should be introduced into the United States only as seed and the stock grown here. But even this is hazardous, since the species may become subject to the attack of an indigenous parasite; consequently there is need for the establishment of extensive arboreta throughout the forest regions of this country where the behavior of exotic species can be studied.

8. Finally, forest pathologists in this country must obtain an extensive knowledge of exotic parasites on trees in order to safeguard our forests.

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